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A Study on the Optimum Shape of Automobile Air Cleaner Diffuser

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Abstract

In the automotive intake system, air cleaner is an essential apparatus to feed clean air into the engine. The air cleaner is one of the most important devices in the intake system. It consists of upper box, lower box, air filter, diffuser and resonator. In particular, the shape of the air cleaner affects the flow and affects the performance of the engine, so careful design is required. In this paper, the new shape of the air cleaner diffuser is modeled through CATIA and the performance improvement by computational fluid dynamics is investigated. Depending on the shape, the pressure drop can be reduced by about 1.7 Pa and the flow noise can be reduced by up to 7.2dB.

Keywords: Intake system, Air cleaner, Diffuser, Air flow, Flow noise

INTRODUCTION

The intake system of an automobile is a device for supplying air necessary for combustion of an engine. The air supplied to the engine contains various substances in the atmosphere, which then damage the major parts of the engine such as the piston or the cylinder when it enters the engine.

The role of the air cleaner is to filter out the air containing foreign substances and to temporarily reduce the air flow rate in the air filter to reduce the noise generated by the intake system [1].

Air cleaner consists of upper box, lower box, air filter, diffuser and resonator. Air introduced into the air cleaner is sucked into the diffuser through the filter and then transferred to the engine. Particularly, when the diffuser is sucked in, the shape of the diffuser and the flow around it can affect the performance of the engine because it shows a large amount of air gathering characteristics [2,3].

In this paper, after confirming the internal flow of the air cleaner, a new diffuser shape is modeled using CATIA and the flow characteristics, flow noise and pressure distribution due to the diffuser are investigated using ANSYS FLUENT.

INTAKE AIR CLEANERANALYSIS

Air cleaner is the part that makes air filtration in air intake system of automobile. In air intake systems, the air cleaner is important enough to influence the overall performance of the inspiratory system. Since each of the elements has a direct effect on performance, they must be carefully designed from the beginning[4,5].

Figure 1 briefly shows the intake system of the vehicle and the components in the air cleaner. The overall air flow is as shown in the arrow in Figure 1, and air entering through the snorkel enters the air cleaner through the air duct, is sucked through the filter into the diffuser, and then flows into the engine.

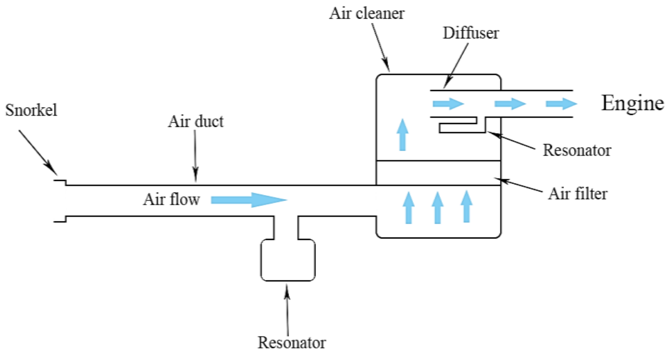


Figure 1 : Simple structural diagram in an intake system

ANALYSIS OF FLOW AND FLOW NOISE AND PRESSURE DISTRIBUTION OF AIR CLEANER

Analysis Modeling

In order to analyze the pressure, flow and flow noise inside the air cleaner assuming the running condition of the vehicle, the air cleaner in the car is modeled as shown in figure 2 using CATIA. The shape of the diffuser in the air cleaner is the same as that in Fig. 2, and the flow of air in the interior follows the following arrows.

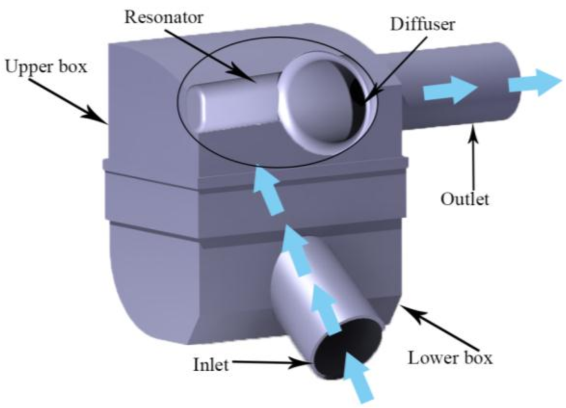


Figure 2: Intake air cleaner model

Cell Zone Definition

The air filter in the air cleaner uses a porous media setting supported by Fluent because it is difficult to generate a lattice because of its complicated shape. The effect on the shape was expressed without implementing the detailed shape of the filter. The loss value was applied using Darcy's Law, and the viscous resistance equation derived from the permeability & loss coefficients equation is as shown in Equation 1 and the inertial resistance equation is as shown in Equation 2. The calculated input values are shown in Table 1 [6].

$$\frac{1}{K_{perm}} = \frac{150}{{D_p}^2}\frac{(1-\epsilon)^2}{\epsilon^3} \qquad (1)$$

$$K_{loss} = \frac{3.5}{D_p}\frac{(1-\epsilon)}{\epsilon^3} \qquad (2)$$

$\frac{1}{K_{perm}}$ is viscous resistance, k_{loss} is inertial resistance, D_p is filter depth and ϵ is the filter porosity. [6]

Table 1: Cell zone condition in air filter

Condition	Value
Filter Porosity	0.85
Viscous Resistance	2487.83 1/m^2
Inertial Resistance	18.1888 1/m

Solver Set Up

Analysis was performed by assuming the flow inside the air cleaner as an incompressible perfect turbulent flow and by using the stabilized and the most frequently employed k-ε Realizable model for reproduction of a turbulent flow. In order to analyze the pressure, PESTO! calculation method suitable for porous media calculation is used. Details Solver Set Up is shown in Table 2.

Table 2: Solver set up

Condition	Value
Solution Method	Steady state
Solution Algorithm	Simple
Turbulence Model	k-ε model
Interpolation Methods for Pressure	PESTO!

Boundary condition

The information on the air characteristics and boundary conditions in the inlet and outlet are shown in Table 3, and the respective values are measured values. The rpm is assumed to be 3500, and the pressure and flow at the corresponding rpm are as follows.

Table 3: Boundary condition in aircleaner

Condition	Value
Mass flow rate	171 kg/h
Inlet pressure	Atmosphere pressure
Outlet Pressure	-1322Pa
Air Density	1.225 kg/m^3
Air Viscosity	1.7894x10^{-5}kg/m·s

FLOW CHARACTERISTICS IN NORMAL AIR CLEANER

In order to confirm the flow characteristics, flow noise and pressure drop of the air cleaner, a normal air cleaner without shape change was investigated through finite element analysis. Figure 3 shows the streamline inside the air cleaner. The air introduced through the inlet rotates along the wall of the upper box through the filter and shows the shape sucked through the diffuser. Especially, the air which is not sucked into the diffuser is circulating through the air cleaner and shows the suction flow. Figure 4 shows the flow noise of a normal air cleaner, with 83.7 dB of flow noise occurring at the edge of the diffuser. Also, it was confirmed that the pressure drop occurred at 138.9 Pa.

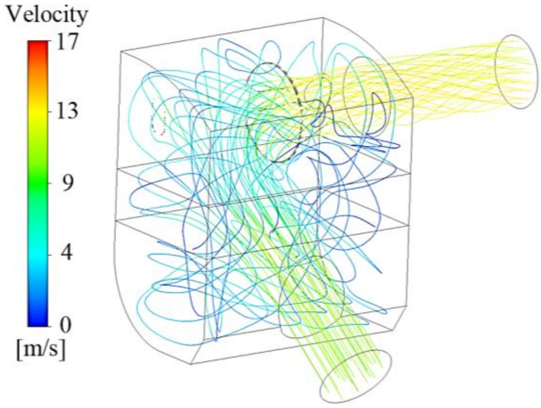


Figure 3: Streamline in normal air cleaner model

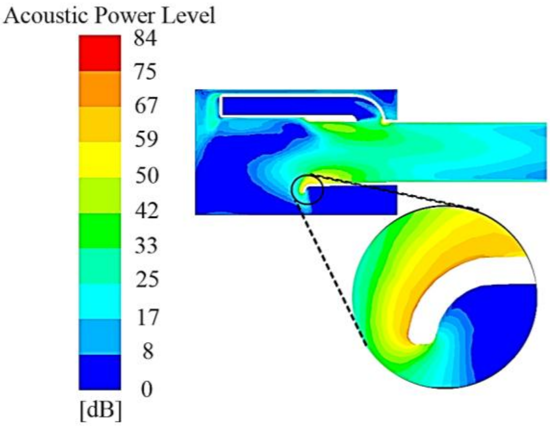


Figure 4: Air flow noise in normal air cleaner

AIR CLEANER OPTIMIZATION THROUGHT GEOMETRY CHANGE

Analysis modeling

Considering the flow characteristics of the normal air cleaner, a diffuser shape with one side longer and 25 ° inclined was created as shown in figure 5.Also, it was confirmed that the flow noise occurred in the edge part of the diffuser, and the radius value was changed as shown in figure 6, respectively. Table 4 shows the details of each case.

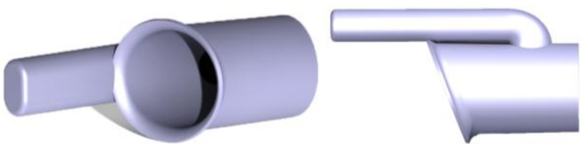


Figure 5: Curved diffuser model

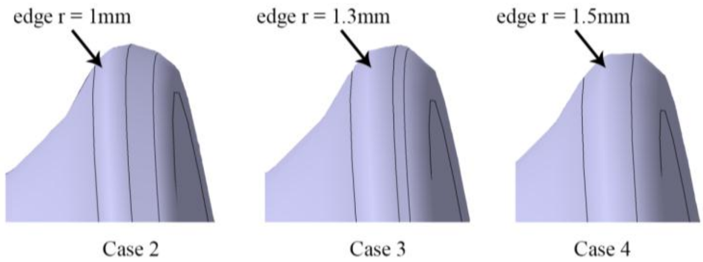


Figure 6: Edge shape of curved diffuser

Table 4: Inner structure variation of air cleaner

Model	Inner structure variation of air cleaner
Case 1	Normal air cleaner
Case 2	Curved diffuser with edge r = 1 mm
Case 3	Curved diffuser with edge r = 1.3 mm
Case 4	Curved diffuser with edge r = 1.5 mm

Flow characteristics of air cleaner with changed shape

Figure 8a shows the stream line in each case's air cleaner. The air cleaner equipped with a curved diffuser generally has more diffused air than the case with a normal diffuser, the spiral vortex around which air was not sucked also decreased. Figure 8b shows the vector flow in section A-A 'in figure 7, showing that the shorter part of the diffuser sucks the surrounding air more effectively than the normal diffuser. Also, it is considered that the edge part of the diffuser does not have a influence on the flow. The reason for the flow of the flow in the curved diffuser is that the air in the wall is absorbed effectively at the elongated part of the diffuser and the air that can't suck at the shortened part is inhaled before it spreads to the air cleaner as a whole.

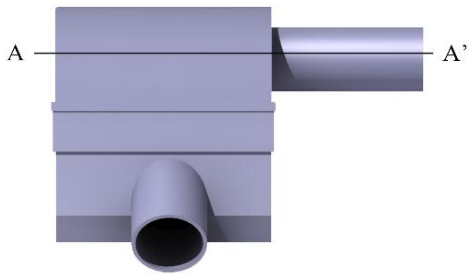
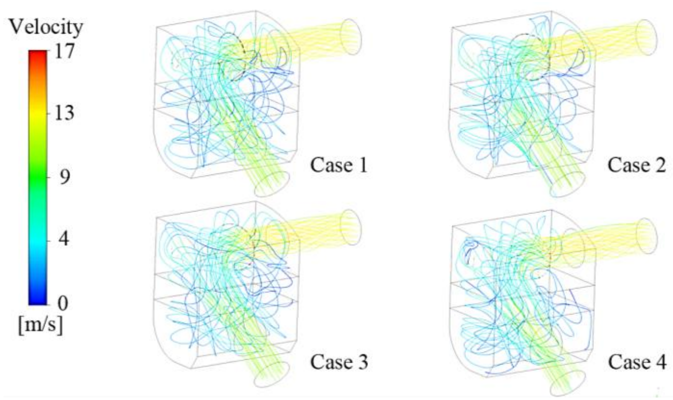
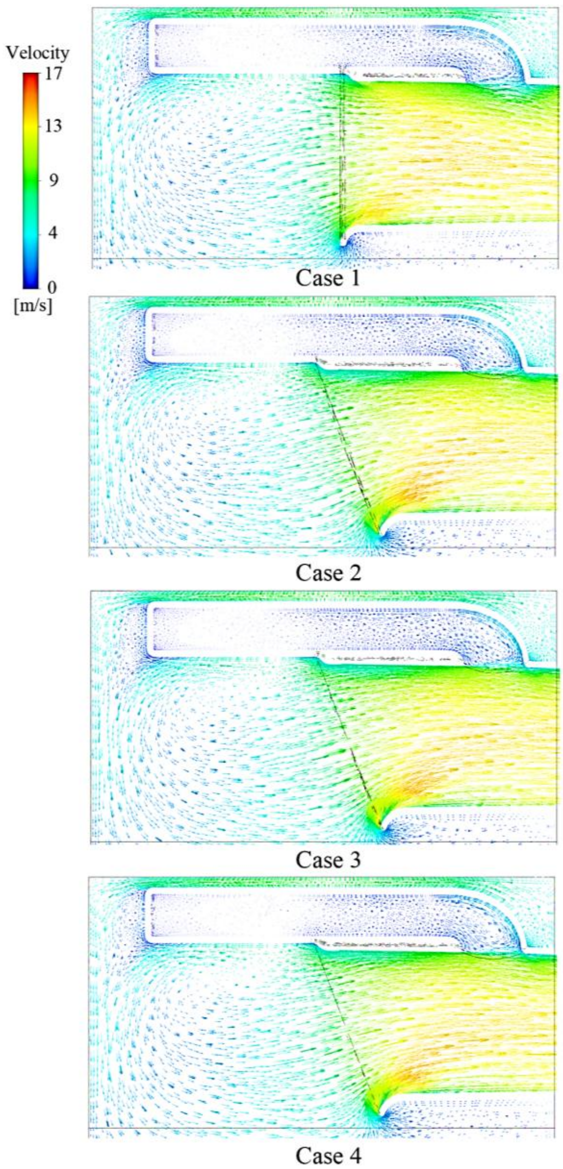


Figure 7: Cross section in air cleaner



(a) Streamline in each case of air cleaner model



Cross section A-A'

(b) Velocity vector in each case of air cleaner model

Figure 8: Velocity distribution of air cleaner

Flow noise characteristics of air cleaner with changed shape

It was confirmed that the portion of the normal air cleaner where the flow noise is generated is the edge of the diffuser. Then, the flow noise was measured by changing the radius value of the edge in the shape of the newly created curved diffuser. The measured values are shown in Table 5.Most of the flow noise was generated at the edge of the diffuser, and the curved diffuser generated much noise at the short side edge. The case 2 with the same radius value as the normal diffuser was measured at a maximum of about 4.3 dB lower, and the flow noise tended to decrease as the radius value of the edge increased. The improved diffuser and edge geometry resulted in a maximum reduction of 7.2 dB.

Table 5: Flow noise in each case of air cleaner

Model	Acoustic power level
Case 1	83.68 dB
Case 2	79.38 dB
Case 3	78.41 dB
Case 4	76.47 dB

Pressure Distribution Characteristics of air cleaner with changed shape

As shown in Table 6, the characteristics of pressure distribution by diffuser shape and edge were investigated. The curved diffuser showed about 1.3Pa improvement compared to the normal diffuser and the improvement effect according to edge type was small. The improvement effect of curved diffuser and edge type was measured at about 1.7 Pa.

Table 6: Pressure drop of each air cleaner model

Model	Pressure drop (Inlet-Outlet)
Case 1	138.86 Pa
Case 2	137.53 Pa
Case 3	137.36 Pa
Case 4	137.14 Pa

CONCULUSION.

In this paper, the efficient shape of the diffuser in the air cleaner of the intake system is discussed and the following results are obtained through finite element analysis.

1) It was confirmed that a large amount of rotating flow occurred in the upper box of the air cleaner.

2) By improving the curved diffuser and edge shape

made considering the flow of the air cleaner, the flow noise can be reduced by up to 7.2 dB.

3) In terms of pressure drop, the new diffuser shape was improved by 1.7 Pa at maximum, and the pressure improvement effect by the edge was negligible.

ACKOWLEDGMENTS

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